Upgrading EMMA to Accelerate Slowly with Low-Frequency RF

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Outline

- Current EMMA main ring
- Motivation for changing the RF system
- Required changes to EMMA
  - RF system
  - Lattice
  - Diagnostics
- Time scale

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Current EMMA Main Ring Motivation: Muon Acceleration

- Original motivation for non-scaling FFAGs
- Extremely rapid acceleration
  - Resonance crossing less of a concern
- Relativistic beam
- Compact apertures to keep costs reasonable
- Must use high-, fixed-frequency RF (200 MHz)
- Large transverse emittance (30 mm norm.!)

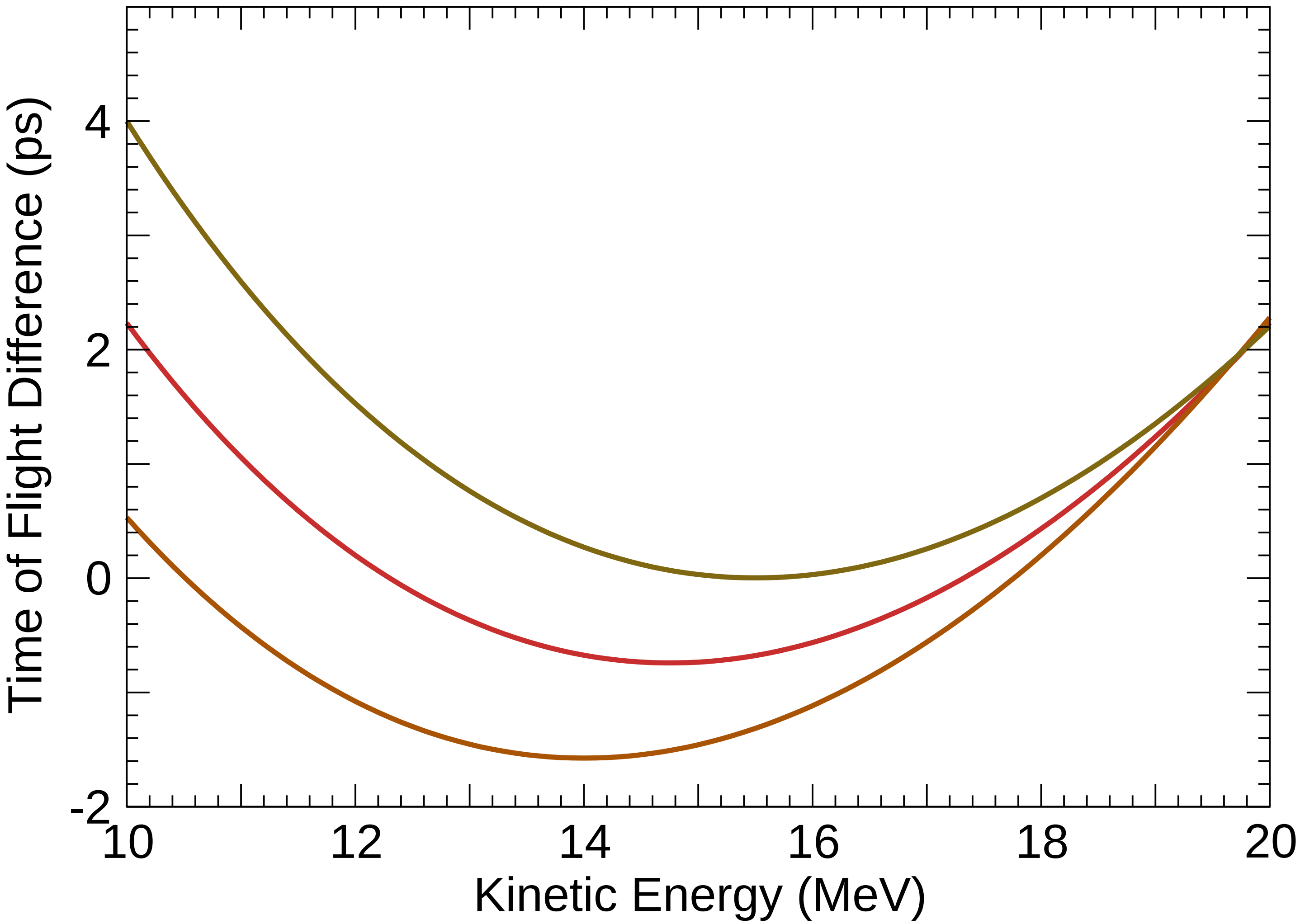
Current EMMA Main Ring Motivation: EMMA Design

- Muon application was most well-understood
- Logical choice for EMMA design
- Parameter choices: rough scaling of muon acceleration
  - 1.3 GHz RF frequency
  - 10–20 MeV energy range
  - Accelerate in around 10 turns
  - 3 mm normalized acceptance

Motivation for Low-Frequency RF
Non-Muon Applications

- Non-muon applications: slower acceleration
  - Medical
  - High-power proton beam
  - Low frequency, low voltage
- Can't accelerate slowly with high-frequency RF
  - Time of flight varies with energy
  - RF frequency fixed
  - Bunch leaves RF crest

Time of Flight vs. Energy



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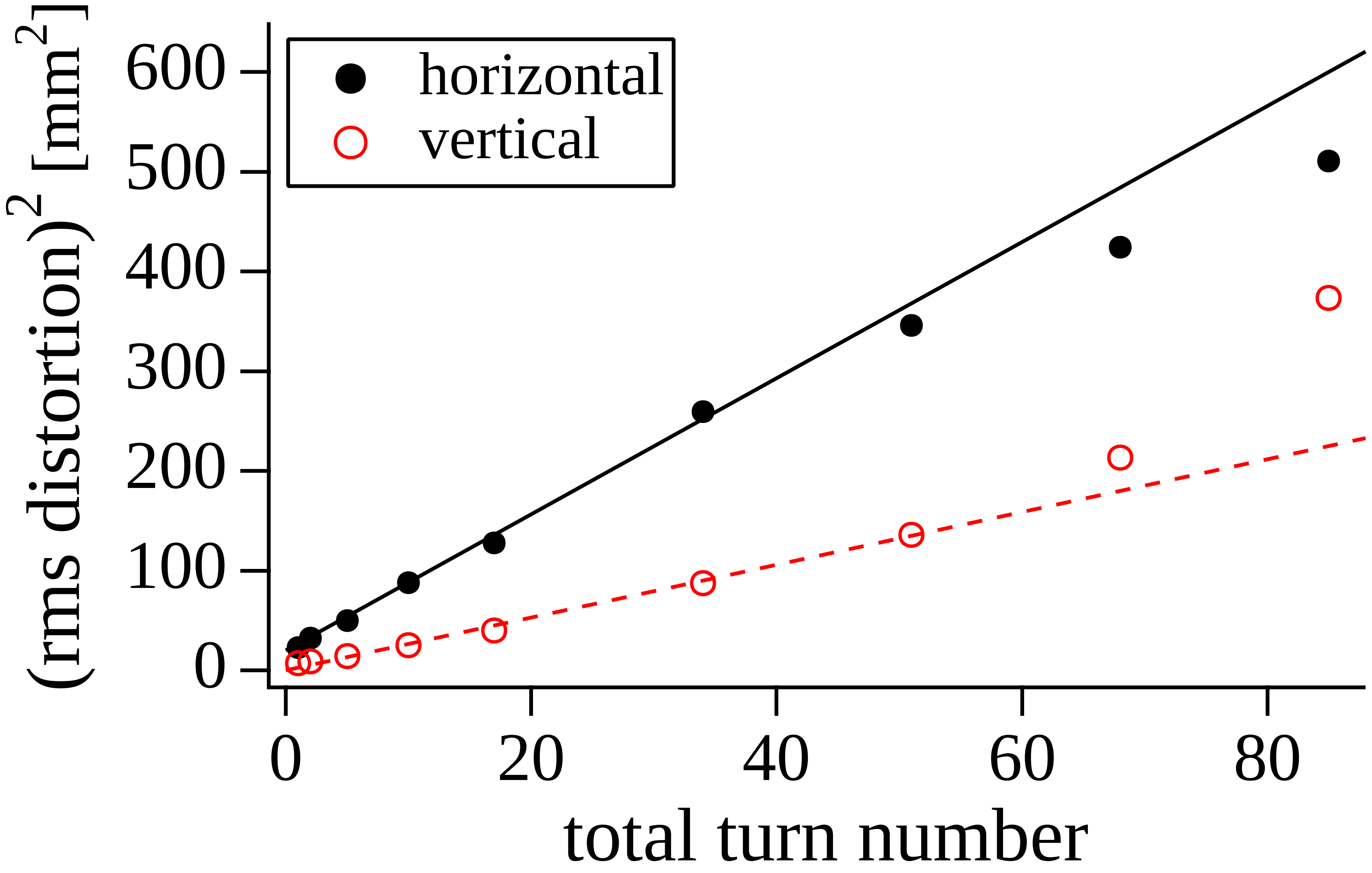
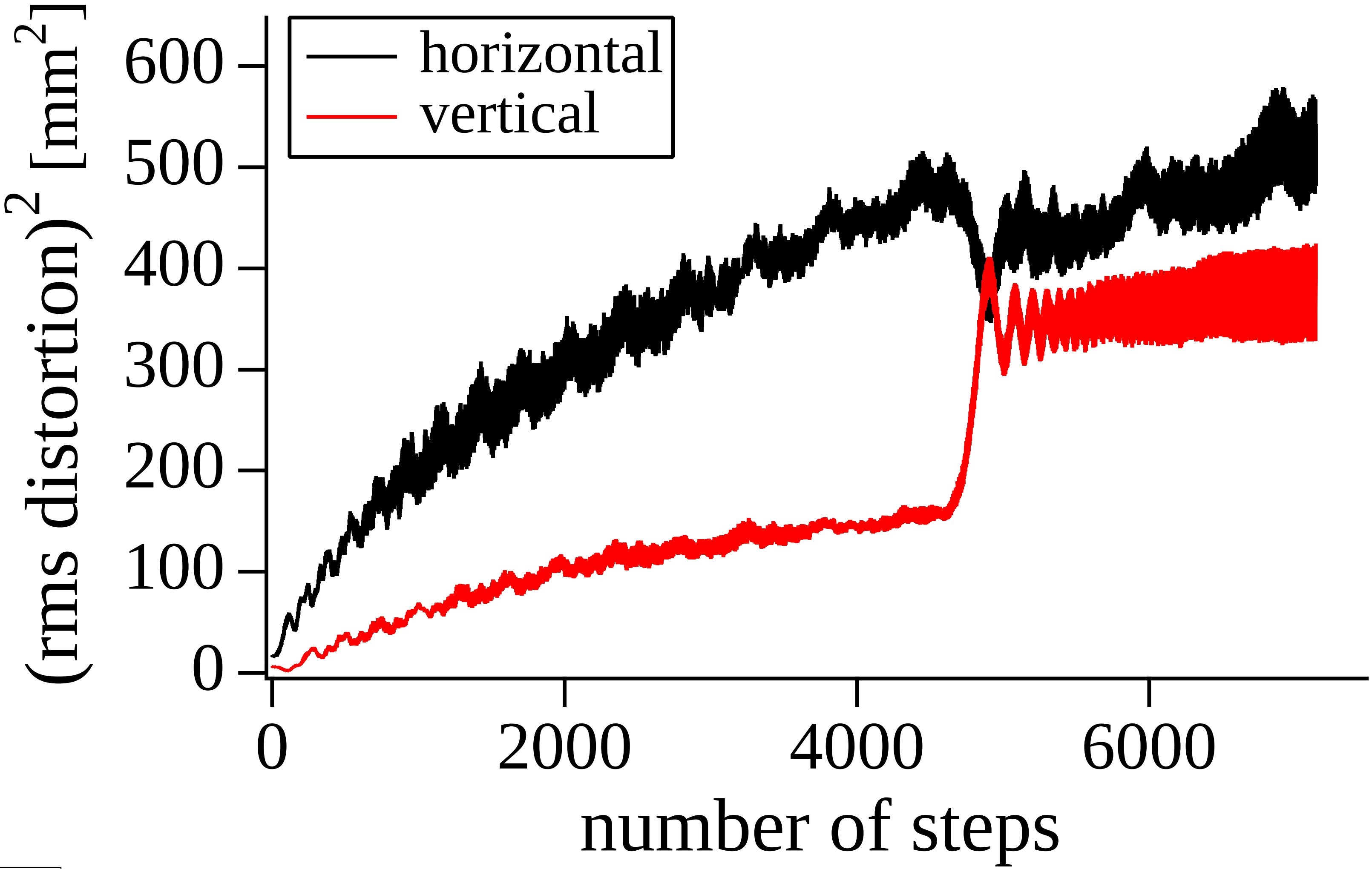
Motivation for Low-Frequency RF Beam Dynamics

- Nonlinear resonances
  - Magnet ends
  - Large beam angles
- Imperfection resonances
  - Lattice errors
  - Perturbations at injection/extraction
- Resonances are crossed slowly
- Small emittance beams

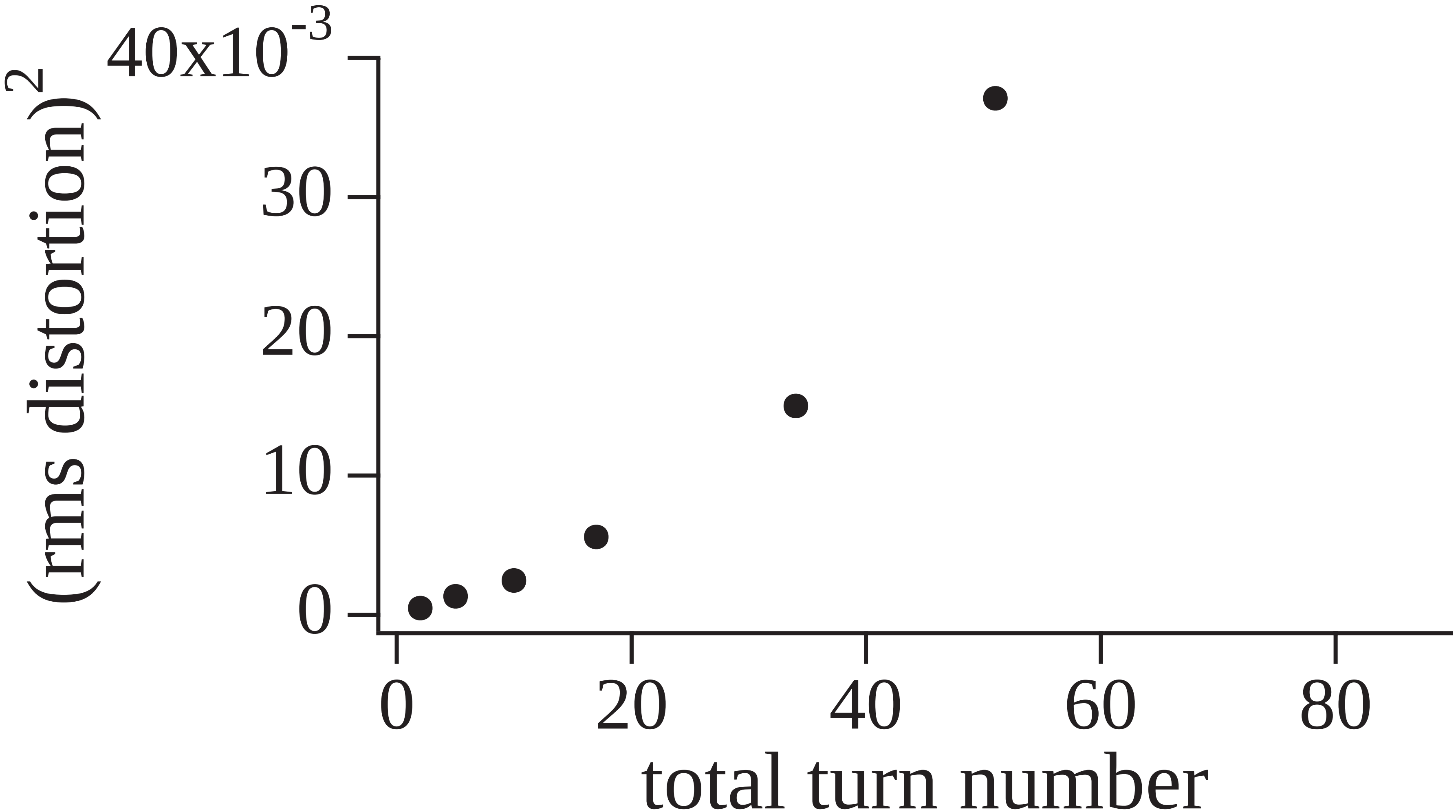
Distortion (Dipole) vs. Acceleration Rate (Machida and Kelliher)



Crossing Nonlinear Resonance (Machida and Kelliher)



Distortion (Quad) vs. Acceleration Rate (Machida and Kelliher)



Motivation for Low-Frequency RF
Questions to be Answered

- What is the minimum rate at which we can accelerate?
- How is emittance growth related to
  - Acceleration rate
  - Initial emittance
  - Which resonances we cross (tune)
  - Lattice errors

Required Changes to EMMA RF System

- Harmonic 1 for EMMA is about 18 MHz
  - Is there a reason to go higher?
- Accelerate from 10 to 20 MeV in 100 turns
  - Insure success, see growth before failure
  - 100 kV of RF (that’s a lot!)
- Cavities must fit in 10 cm gap
- Prefer uniformly distiributed cavities
  - Emittance growth from discretization

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Required Changes to EMMA RF System: Frequency Variation

- No lattice changes, fixed 18 MHz frequency
  - Serpentine ($a = 1/12$) permits $\leqslant$850
- No lattice change, follow beam frequency
  - About 55 kHz frequency variation
  - Time at least 2.8 μs (50 turns: half cycle)
- Change lattice to get synchrotron oscillations
  - Guess: 650 kHz frequency variation
  - Lattice may not be possible. . .

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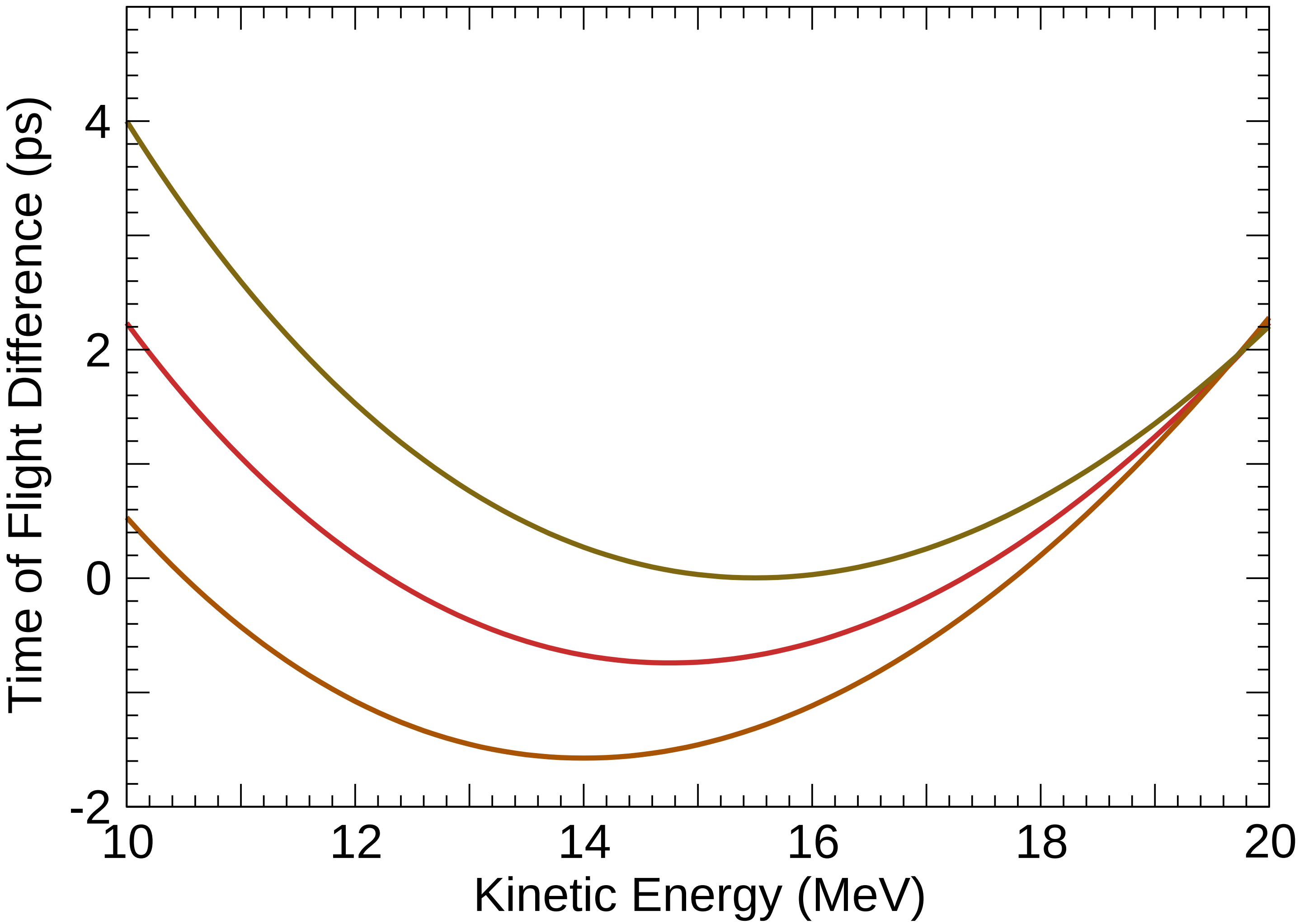
Required Changes to EMMA Lattice

- Lattice may not need to be changed
- Adjustments are possible: small emittance
  - Vacuum chamber blocks magnet motion?
- Adjustment desirable: synchotron motion
  - Eliminate isochronous point in energy range
    - May not be possible
  - Model longitudinal motion in slow acceleration applications

Time of Flight vs. Energy



Required Changes to EMMA Diagnostics

- Significantly smaller emittance
  - ALICE native emittance
- Accurately measure beam before and after
  - Probably at the 10% level
- Must have good matching
  - Not so important for large painted emittance
  - We may achieve this anyhow

Time Frame

- EMMA scheduled to run through fall 2010
- Second year of running: through fall 2011
  - We have more to do than can be accomplished in one year
- Submit low frequency proposal after successful EMMA acceleration: spring 2010
  - Begin working on proposal in spring 2009
- Install and test low frequency fall 2011–fall 2012
- Run fall 2012–fall 2013